Highly birefringent multicore optical fibers

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Abstract: We report on the fabrication and characterization of two polarization maintaining multicore fibres, one with three and the other with ninety eight cores. The beat length and polarization orientation are characterized.

OCIS codes: 060.2280, 060.2420, 170.2150.

1. Introduction

Multicore fibers have received attention recently for both telecommunications applications and for endoscopic applications. Several groups have reported work using multicore fibers as phased arrays for remote multi-photon fluorescence imaging [1], [2]. The potential applications for such systems could be increased if the fibers could be made to deliver polarized light to the target fluorophores. We report the fabrication and characterization of two highly birefringent (HiBi) multicore optical fibers for use in endomicroscopy.

2. Fabrication

Our fibers were fabricated using the stack and draw technique. Individual graded index germanium doped silica rods (Draka-Prysmian: NA=0.21) were used to form the cores and pure silica rods were used elsewhere. In order to form the stress applying regions thin walled capillaries were stacked either side of each core. After the stack was complete boron doped silica rods with a doping concentration of 24% (Draka-Prysmian) were drawn down and inserted into the capillaries either side of each core. In the ninety eight core fibre a row of un doped silica rods separated each layer of cores setting the cores in a rectangular pattern. The stacks were drawn straight to fiber under a low vacuum with no intermediate preform stage. Optical micrographs of the fibres can be seen in fig. 1. The outer diameters of the fibers were 150μm and 125μm, the core diameters were 2.8μm and 3.1μm and boron doped regions were 11μm and 4μm in diameter for the three core fiber and ninety eight core fiber respectively.

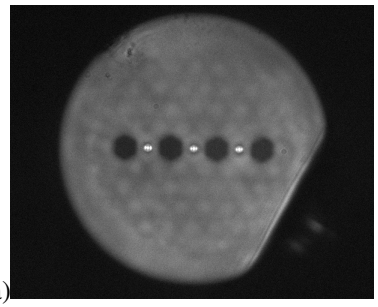
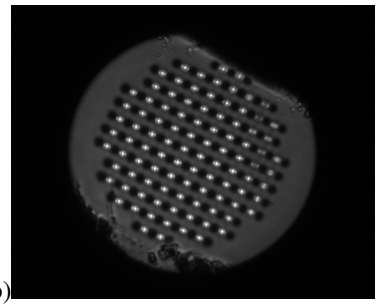
(a)  (b) 

Fig. 1. Optical micrographs of two highly birefringent multicore fibers. (a) Three core design and (b) ninety eight core design. The boron doped regions appear darker than the surrounding silica.

3. Characterization

3.1. Three core fiber

The beat length (L_b) in our three core fiber was measured at 633nm using the scattering method in which direct observation of the polarization mode beating can be seen through the side of the fiber [3]. In all of the cores $L_b \approx 1.9$mm. From this measurement the birefringence can be determined using the relation $B = \lambda / L_b = 3.3 \times 10^{-4}$. This value is comparable to commercially available PANDA and bow-tie fibers [4].

3.2. Ninety eight core fibre

The beat length was measured in a number of cores using the scattering method at 633nm and found to be ≈2.5mm in each case. The calculated birefringence from this measurement is 2.5×10^{-4}.

The orientation of linearly polarized light in several cores was measured. A schematic representation of the fiber can be seen in fig. 2, the cores can be identified by a letter and number. Polarized light with a wavelength of 800nm was coupled into a fiber core through a half wave plate. A polarizer was placed at the fibre output. The half wave plate and polarizer were rotated in order to find the minimum transmission and the angle of the input polarization recorded. This was repeated for all the cores in row 7 and column E. The polarization offset from core E7 is shown in table 1. The polarization orientation of the 22 measured cores were found to lie within 5° of each other, which is within about 2° of the mean orientation.

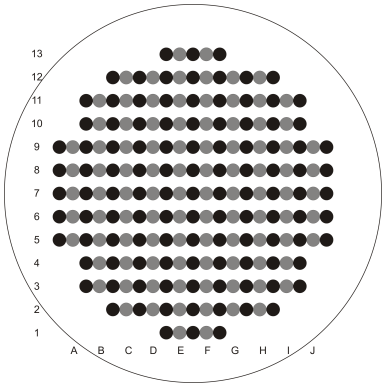


Fig. 2. A schematic diagram showing core notation for the ninety eight core fiber. The locations of germanium doped cores are shown in gray and identified by a letter and number, boron doped regions are indicated in black.

Table 1. Polarization orientation

Core:	A7	B7	C7	D7	E7	F7	G7	H7	I7	J7			
Offset from E7 (degrees):	−2	−2	−2	−1	0	−2	−2	−1	−3	−2			
Core:	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
Offset from E7 (degrees):	−2	0	0	0	0	0	0	0	0	−2	−2	−3	−4

4. Conclusions

Two polarization maintaining multicore fibers were fabricated and found to have comparable birefringence to commercial single core HiBi fibers. For our fiber with multiple rows, and hence out of plane stress rods, the orientation of linearly polarized light in each measured core varies by a maximum of only 5°. The out of plane stress rods and the smaller size of the stress applying regions when compared to the size of the cores are the most likely the causes of the lower birefringence when compared to the in plane three core fiber.

References

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